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Recovery of Macrolichen Flora in the Imperial Palace Ground, Tokyo, Japan

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Sixteen species of macrolichens were collected from the Imperial Palace Ground, Tokyo in 2009 and 2010. Among them, twelve species, *Candelaria concolor*, *Cladonia ramulosa*, *Dirinaria applanata*, *Flavoparmelia caperata*, *Hyperphyscia crocata*, *Parmelinopsis minarum*, *Parmotrema austrosinense*, *P. clavuliferum*, *P. tinctorum*, *Phaeophyscia hispidula*, *Physcia orientalis* and *Punctelia borreri* were newly found during the present investigation. The other four species, *Cladonia caespiticia*, *C. kurokawae*, *Phaeophyscia rubropulchra* and *Physciella melanchra*, have already been reported in an earlier investigation carried out in 1995 and 1996. The thallus of parmelioid lichens were small in size, and ranged from 1.0 to 6.4 cm in diameter. The appearance of the macrolichens seems to be closely related to the remarkable improvement of air pollution due to the strict regulation of exhaust gas from the diesel engine in and around Tokyo since 2003.

Key words: Air pollution, bioindicator, lichen, parmelioid lichens, thallus size, urban area.

The Imperial Palace Ground is located at the center of the urban area in Tokyo metropolis which has some old-growth forest remaining after a period of several centuries in spite of frequent fires caused by, e.g., earlier warfare, earthquakes and World War II. As part of a biological investigation project of the Imperial Palace Ground in Tokyo, conducted by the National Museum of Nature and Science, the authors carried out lichenological field investigations between 26 October 2009 and 14 October 2010. The main purpose of this study is to clarify the difference in the current lichen flora to those reported by Kashiwadani and Thor (1997, 2000). It is particularly noteworthy that 12 macrolichens were newly found in the present study, where only four macrolichens, i.e., *Cladonia caespiticia* (Pers.) Flörke, *C. kurokawae* Ahti & S. Stenroos (as *C. humilis* (With.) J. R. Laundon), *Phaeophyscia rubropulchra* (Degel.) Moberg and *Physciella melanchra* (Hue) Essl. have been reported in the former investigations carried out in 1995 and 1996 (Kashiwadani and Thor 2000).

Materials and Methods

A total of 129 specimens were collected between 26 October 2009 and 14 October 2010 by the authors. The collection sites are shown in Table 1 and Fig. 1. Although the collections

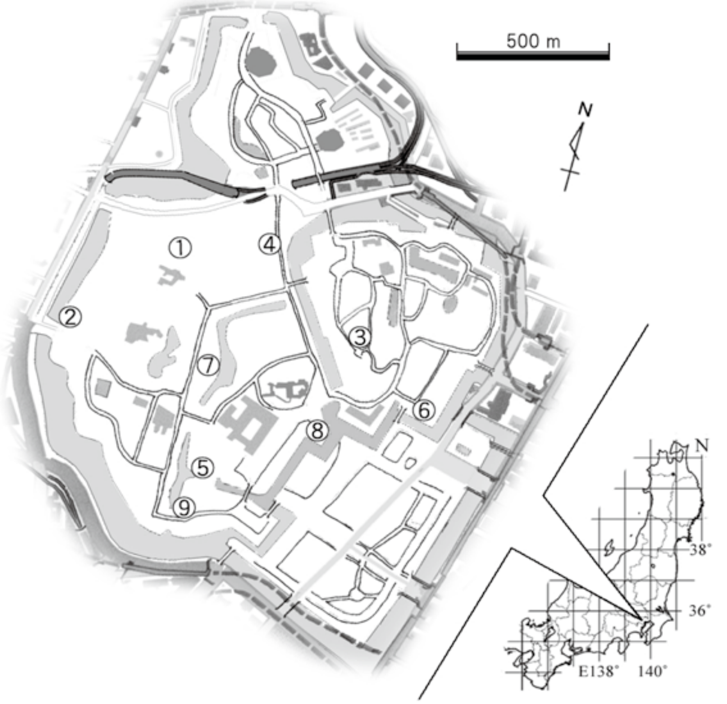

Fig. 1. Collection sites in the Imperial Palace Ground. Locality numbers are identical with those in Table 1. 1. Fukiage-gosho. 2. Hanzobori. 3. Honmaru. 4. Inui-mon avenue. 5. Kamidokanbori. 6. Kikyobori. 7. Ohmichi garden. 8. Sakashita-mon. 9. Sankaku-mon.

include fruticose, foliose and crustose lichens, this study shows the results of taxonomic study for fruticose and foliose lichens. We intend to report on crustose lichens in a future paper. Thallus diameter of parmelioid lichens was measured in the field (other lichens could not be measured because of the ambiguously overlapping colonies). After that, a part of the thallus was collected as a voucher specimen. All specimens are deposited in the herbarium of the National Museum of Nature and Science (TNS). For the identification of specimens, lichen substances were examined by thin layer chromatography (TLC) (Culberson and Johnson 1982). Only the solvent B system was used here.

Results

As a result of taxonomic study, the following species were found in the present area. They are arranged alphabetically. Numerals following abbreviations of localities indicate the collection numbers of Y. Ohmura. The diameter of thallus for parmelioid lichens is shown in the parenthesis after the collection number. The asterisk in the species list indicates the species was also found in the former investigations (Kashiwadani and Thor 2000).

1. ***Candelaria concolor*** (Dicks.) Arnold

Rich populations were found on trunks of *Prunus* and *Liquidambar*.

Specimens examined. Honmaru: 7697, on bark of *Prunus lannesiana*. Inui: 6822, on bark of *Prunus* × *yedoensis* (coll. date 3/12/2009); 6820, 6832, on bark of *Liquidambar formosana* (coll. date 26/10/2009, 3/12/2009 respectively).

2. ****Cladonia caespiticia*** (Pers.) Flörke

Commonly found on soil and rock at

Table 1. List of localities. All localities: Japan, Honshu, Prov. Musashi (Tokyo Metropolis), Chiyoda-ku, Imperial Palace, 35°41′N, 139°45′E

Abbreviation	Locality	Collection date (d/m/y)	Note
Fukiage	Fukiage-gosho, 13 m alt.	26/10/2009	Old growth deciduous forest with paths
Hanzo	Around Hanzobori Moat, 35 m alt.	13/10/2010	West-facing old stone wall, not shaded by trees
Honmaru	Honmaru, Higashi-gyoen, 20 m alt.	14/10/2010	Open place with scattered deciduous trees
Inui	Inui-mon avenue, 10 m alt.	26/10/2009 3/12/2009 4/12/2009 7/1/2010	Avenue with *Acer* and *Prunus* × *yedoensis*
Kamidokan	Around Kami-Dokanbori Moat, 40 m alt.	13/10/2010	West-facing old stone wall surrounded by open forest
Kikyo	Tatsumiyagura, Kikyobori Moat, Higashi-gyoen, 4 m alt.	14/10/2010	Open place with scattered broad-leaf evergreen tree and pine trees
Ohmichi	Ohmichi garden, 10 m alt.	4/12/2009	Nursery with bonsai trees, scattered other trees and greenhouses
Sakashita	Sakashita-mon, 10 m alt.	3/12/2009	Open place nearby the gate with northeast-facing old stone wall
Sankaku	Stonewall near Sankaku-mon, 10 m alt.	4/12/2009	Shaded old stone wall

stonewall and trunk of *Pinus densiflora*. We confirmed the colonies of this species look healthy in the field, although the specimens collected in the former investigation look depauperate. Kashiwadani and Thor (2000) supposed they were influenced by air pollution.

Specimens examined. Inui: 6851, 6852, on trunk and trunk base of *Pinus densiflora* (coll. date 4/12/2009). Kamidokan: 7686, 7689, on stone wall. Sankaku: 6858, 6859, on soil.

3. ***Cladonia kurokawae*** Ahti & S. Stenroos

Commonly found on mortar of stone walls and trunk base of *Pinus densiflora*. As in the case of *C. caespiticia*, the colonies look healthy at this time but it was depauperate at the time of former investigation.

This species was reported as "*C. humilis* (With.) J. R. Laundon" in Kashiwadani and Thor (2000). However, the individuals collected in this area have granulose podetia which are characteristics for *C. kurokawae*. While *C. humilis* has farinosely sorediate podetia, and is rarely found in Japan (Ahti et al. 1996).

Specimens examined. Hanzo: 7653, on soil. Inui: 6854, on trunk base of *Pinus densiflora* (coll. date 4/12/2009). Kikyo: 7694, on moss. Sakashita: 6845, over moss on stonewall.

4. ***Cladonia ramulosa*** (With.) J. R. Laundon

The specimens have no apothecia and look depauperate, but the individuals have features of this species, i.e., having slender podetia (4 to 12 mm in length) without soredia and containing fumarprotocetraric and homosekikaic acids as major substances. There seem to be rare populations in the Imperial Palace Ground.

Specimens examined. Hanzo: 7664, on soil. Ohmichi: 6857, on humus.

5. ***Dirinaria applanata*** (Fée) D. D. Awasthi

Rich populations were found on trunks of *Prunus* ×*yedoensis*.

Specimens examined. Inui: 6818, 6821, 6828, on bark of *Prunus* ×*yedoensis* (coll. date 26/10/2009 for 6818; 3/12/2009 for 6821, 6828).

6. ***Flavoparmelia caperata*** (L.) Hale (Fig. 2A)

Only three thalli were found.

Specimens examined. Inui: 6862 (1.1 cm), 6863 (6.4 cm), 6867 (1.2 cm), on bark of *Prunus* ×*yedoensis* (coll.

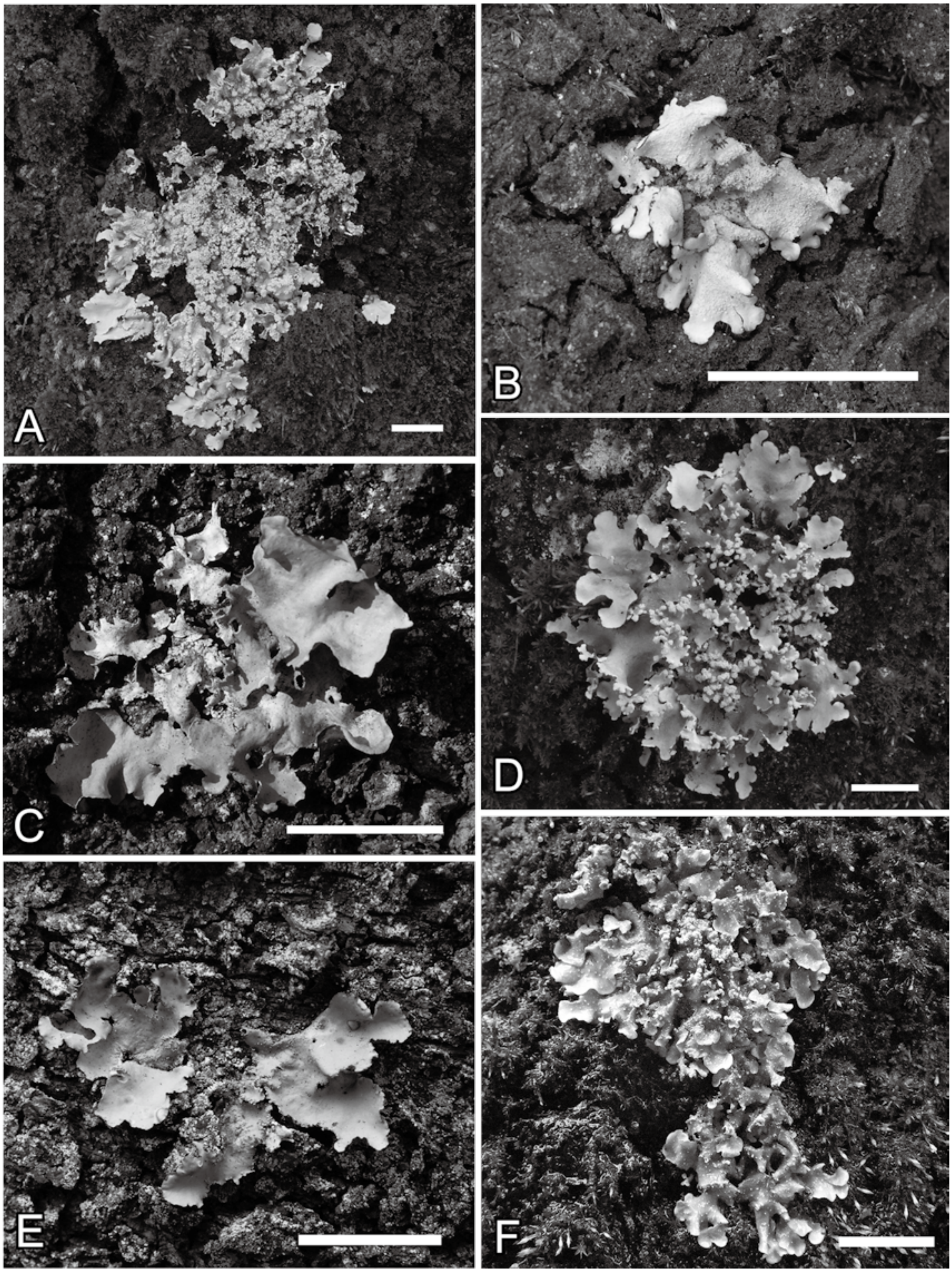

Fig. 2. Parmelioid lichens found in the Imperial Palace. A. *Flavoparmelia caperata* (YO 6863). B. *Parmelinopsis minarum* (YO 6870). C. *Parmotrema austrosinense* (YO 6868). D. *P. clavuliferum* (YO 6829). E. *P. tinctorum* (YO 6869). F. *Punctelia borreri* (YO 6831). Numerals following YO indicate the collection numbers of Y. Ohmura in TNS. Scales = 1 cm.

date 7/1/2010).

7. ***Hyperphyscia crocata*** Kashiw.

Rich populations were found on trunks of *Liquidambar formosana* and *Zelkova serrata* and on stone walls.

Specimens examined. Inui: 6838, 6840, on bark of *Liquidambar formosana* (coll. date 3/12/2009). Kamidokan: 7688, on stone wall. Honmaru: 7701, on bark of *Zelkova serrata*.

8. ***Parmelinopsis minarum*** (Vain.) Elix & Hale (Fig. 2B)

Only one small thallus was found.

Specimens examined. Inui: 6870 (1.2 cm), on bark of *Prunus ×yedoensis* (coll. date 7/1/2010).

9. ***Parmotrema austrosinense*** (Zahlbr.) Hale (Fig. 2C)

Only two small thalli were found.

Specimens examined. Inui: 6865 (1.8 cm), on bark of *Pinus thunbergii*; 6868 (2.5 cm), on bark of *Prunus ×yedoensis* (coll. date 7/1/2010).

10. ***Parmotrema clavuliferum*** (Räsänen) Streimann (Fig. 2D)

Only two thalli were found.

Specimens examined. Inui: 6817 (2.0 cm), 6829 (5.5 cm), on bark of *Prunus × yedoensis* (coll. date 26/10/2009, 3/12/2009 respectively).

11. ***Parmotrema tinctorum*** (Despr. ex Nyl.) Hale (Fig. 2E)

Only three thalli were found.

Specimens examined. Inui: 6824 (1.0 cm), 6861 (1.0 cm), 6869 (1.4 cm), on bark of *Prunus × yedoensis* (coll. date 3/12/2009 for 6824; 7/1/2010 for 6861, 6869).

12. ***Phaeophyscia hispidula*** (Ach.) Essl.

Rich populations were found on trunks of *Prunus* and *Liquidambar*.

Specimens examined. Fukiage: 6807, on bark of *Prunus mume*. Inui: 6836, 6837, 6842, 6846, 6847, on bark of *Liquidambar formosana* (coll. date 3/12/2009 for 6836, 6837, 6842; 4/12/2009 for 6846, 6847).

13. ****P. rubropulchra*** (Degel.) Moberg

Rich populations were found on trunk of *Zelkova serrata* and on stone wall.

Specimens examined. Kamidokan: 7676, 7683, 7685, 7690, on stone wall. Honmaru: 7699, on bark of *Zelkova serrata*.

14. ***Physcia orientalis*** Kashiw.

Only two thalli were found.

Specimens examined. Inui: 6848, 6850, on bark of *Prunus ×yedoensis* (coll. date 4/12/2009).

15. ****Physciella melanchra*** (Hue) Essl.

Commonly found on trunks of *Prunus*, *Zelkova* and *Liquidambar*.

Specimens examined. Fukiage: 6802, 6803, on bark of *Prunus jamasakura*. Honmaru: 7698, on bark of *Zelkova serrata*. Inui: 6819, 6833, 6835, 6841, on bark of *Liquidambar formosana* (coll. date 26/10/2009 for 6819; 3/12/2009 for 6833, 6835, 6841).

16. ***Punctelia borreri*** (Sm.) Krog (Fig. 2F)

Only one thallus was found.

Specimens examined. Inui: 6831 (2.9 cm), on bark of *Prunus ×yedoensis* (coll. 3/12/2009).

Discussion

In the investigation carried out in 1995 and 1996, only four macrolichen species were found (Kashiwadani and Thor 2000). Such poor occurrence of macrolichen has been familiar in urban areas of Japan mainly because of air pollution (Sugiyama et al. 1976, Taoda 1992, Hamada et al. 1995). In 2003, the strict regulation of exhaust gas from diesel engines was enforced in and around Tokyo, and the air quality of Tokyo has been remarkably improved after the regulation. The annual average concentration of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and suspended particulate matter (SPM) near the Imperial Palace Ground were 0.014 ppm (SO_2), 0.052 ppm (NO_2) and 0.073 mg/m^3 (SPM) in 1995, and they decreased to 0.005 ppm (SO_2), 0.047 ppm (NO_2) and 0.035 mg/m^3 (SPM) in 2008 (National Institute for Environmental Studies 2011). In the current investigation carried out in 2009 and 2010, we found sixteen species of macrolichens. The drastic recovery of the macrolichen flora in the Imperial Palace Ground is probably related to the improvement of air quality since lichens are known to recover with declining air pollution (Henderson-Sellers and Seaward 1979, Rose and Hawksworth 1981, Showman 1981, Hawksworth and McManus 1989, Cook et al. 1990, Ohmura et al. 2008). This is the first report of the rich macrolichen flora including parmelioid species in central Tokyo although the presence of *Parmotrema austrosinense*, *P.*

tinctorum and/or *Punctelia borreri* were reported from suburbs of Tokyo (Taoda 1992, Kon 2009).

The thalli of these macrolichens found in the Imperial Palace Ground are still small in size (mostly less than 3 cm in diameter for parmelioid lichens). As lichens are known to be suppressed by low air quality such as air pollution, aridification and alteration of pH (Gilbert 2000). Further monitoring of these macrolichens should be made in order to check their stable settlement against the air quality improvement.

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大村嘉人[a]，柏谷博之[a]，文 光喜[b]：**皇居における大型地衣類相の回復**

2009～2010年に皇居内で実施した地衣類調査において，16種の大型地衣類の生育が確認された．1995～1996年に実施された前回の調査では，ドテハナゴケ *Cladonia caespiticia*，ヒメジョウゴゴケ *C. kurokawae*，コナアカムカデゴケ *Phaeophyscia rubropulchra*，ロゼットチイ *Physciella melanchra* のみが見つかっていたが，今回の調査で，ロウソクゴケ *Candelaria concolor*，ヒメレンゲゴケ *Cladonia ramulosa*，コフキメダルチイ *Dirinaria applanata*，キウメノキゴケ *Flavoparmelia caperata*，コカゲチイ（*Hyperphyscia crocata* に対する新称），トゲウメノキゴケ *Parmelinopsis minarum*，ナミガタウメノキゴケ *Parmotrema austrosinense*，マツゲゴケ *P. clavuliferum*，ウメノキゴケ *P. tinctorum*，アラゲクロムカデゴケ（*Phaeophyscia hispidula* に対する新称），シロムカデゴケ *Physcia orientalis*，ハクテンゴケ *Punctelia borreri* の生育が新たに確認された．最も大きかった個体はキウメノキゴケの直径6.4 cmであったが，多くのウメノキゴケ類の地衣体では直径1～3 cm程度であった．地衣類は大気汚染の改善によって回復することが知られているが，本調査地域内での地衣類

の回復は，2003年から始まった首都圏でのディーゼル規制の効果による大気清浄化と関連していることが考えられた．

なお，ヒメジョウゴゴケは*Cladonia conistea* Asahina, nom. invalidに当てられた和名であるため，新たに与えられた命名規約上の学名*C. kurokawae* Ahti & S. Stenroosに対して本和名を用いる．同種と考えられていた*C. humilis* (With.) J.R. Laundonは*C. kurokawae*とは別種とされるため，*C. humilis*をヒメジョウゴゴケモドキ（新称）と呼ぶことにする．

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